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(54) **FLEXIBLE FLAT EMITTER FOR X-RAY TUBES**

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H01J 9/04	(2006.01)
H01J 1/16	(2006.01)

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CPC ***H01J 35/06*** (2013.01); ***H01J 1/16*** (2013.01); ***H01J 9/042*** (2013.01); ***H01J 35/02*** (2013.01)

(58) **Field of Classification Search**

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See application file for complete search history.

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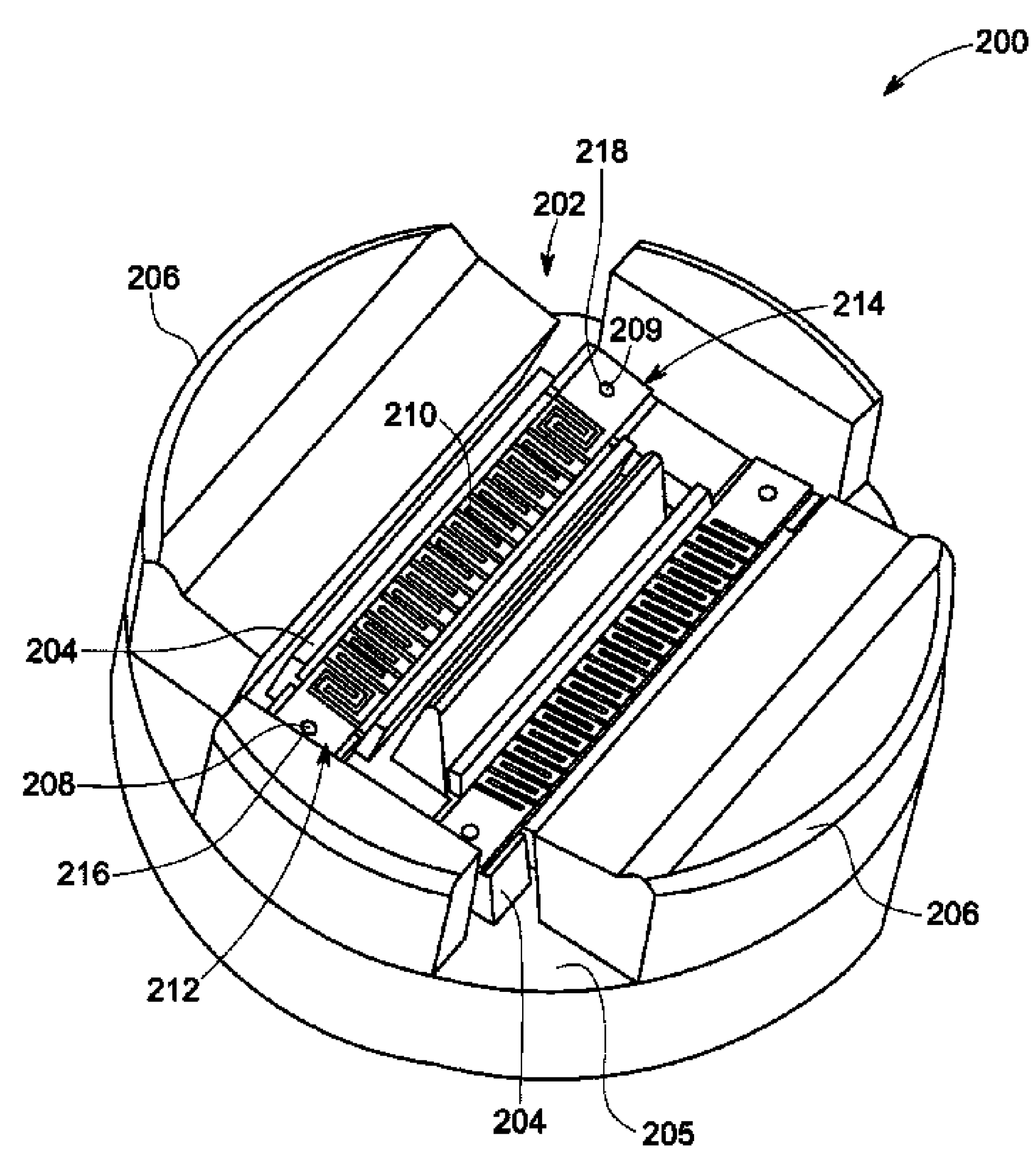
(57) **ABSTRACT**

A flat emitter configured for use in an X-ray tube is presented. The X-ray tube includes a first conductive section including a first terminal. Further, the X-ray tube includes a second conductive section including a second terminal. Also, the X-ray tube includes a third conductive section disposed between the first conductive section and the second conductive section, wherein the third conductive section is configured to emit electrons toward a determined focal spot, and wherein the third conductive section includes a plurality of slits subdividing the third conductive section into a winding track coupled to the first conductive section and the second conductive section, wherein at least two of the plurality of slits are interwound spirally to compose the winding track, and wherein the winding track is configured to expand and contract based on heat provided to the third conductive section.

21 Claims, 6 Drawing Sheets



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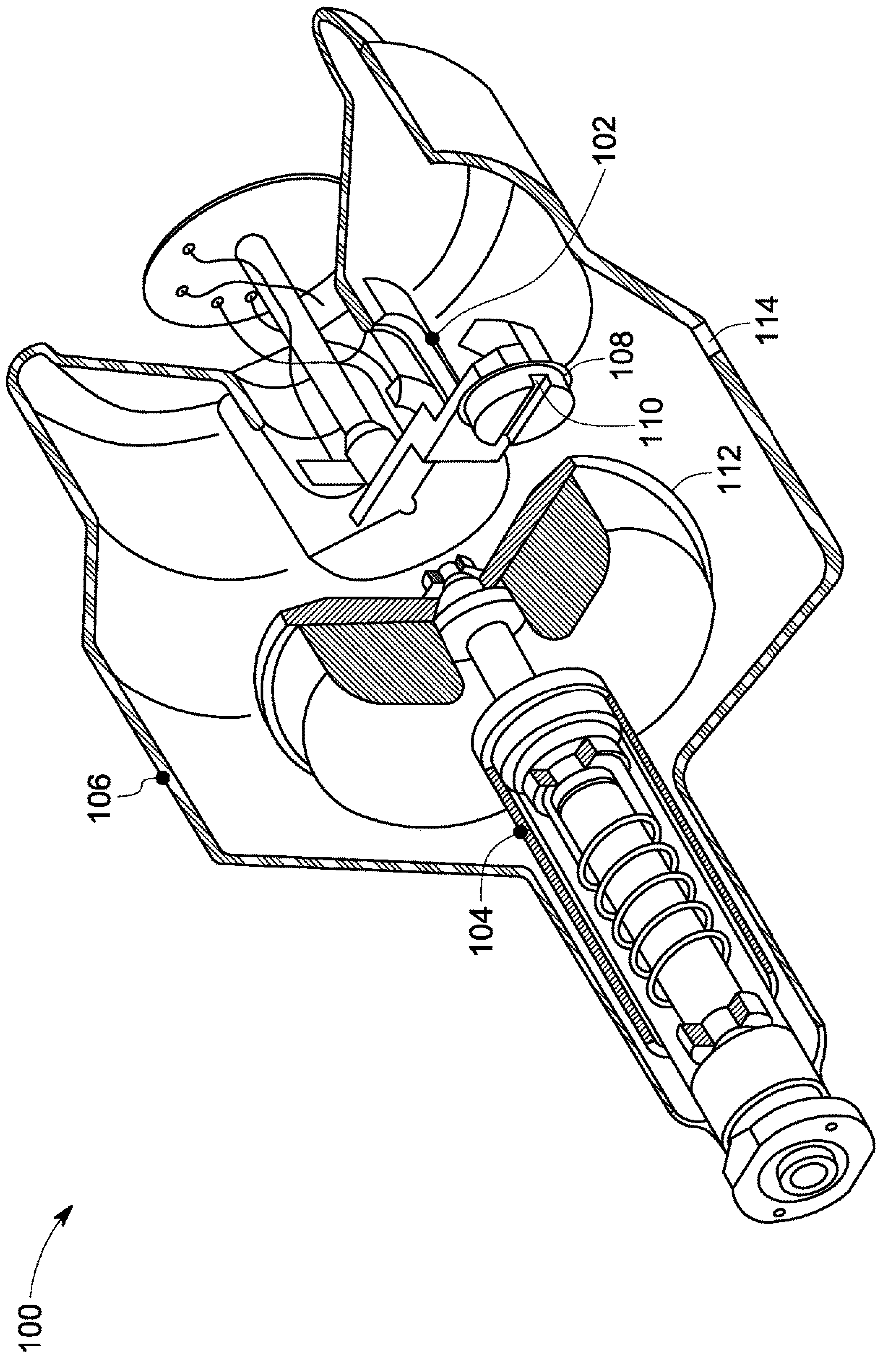

FIG. 1

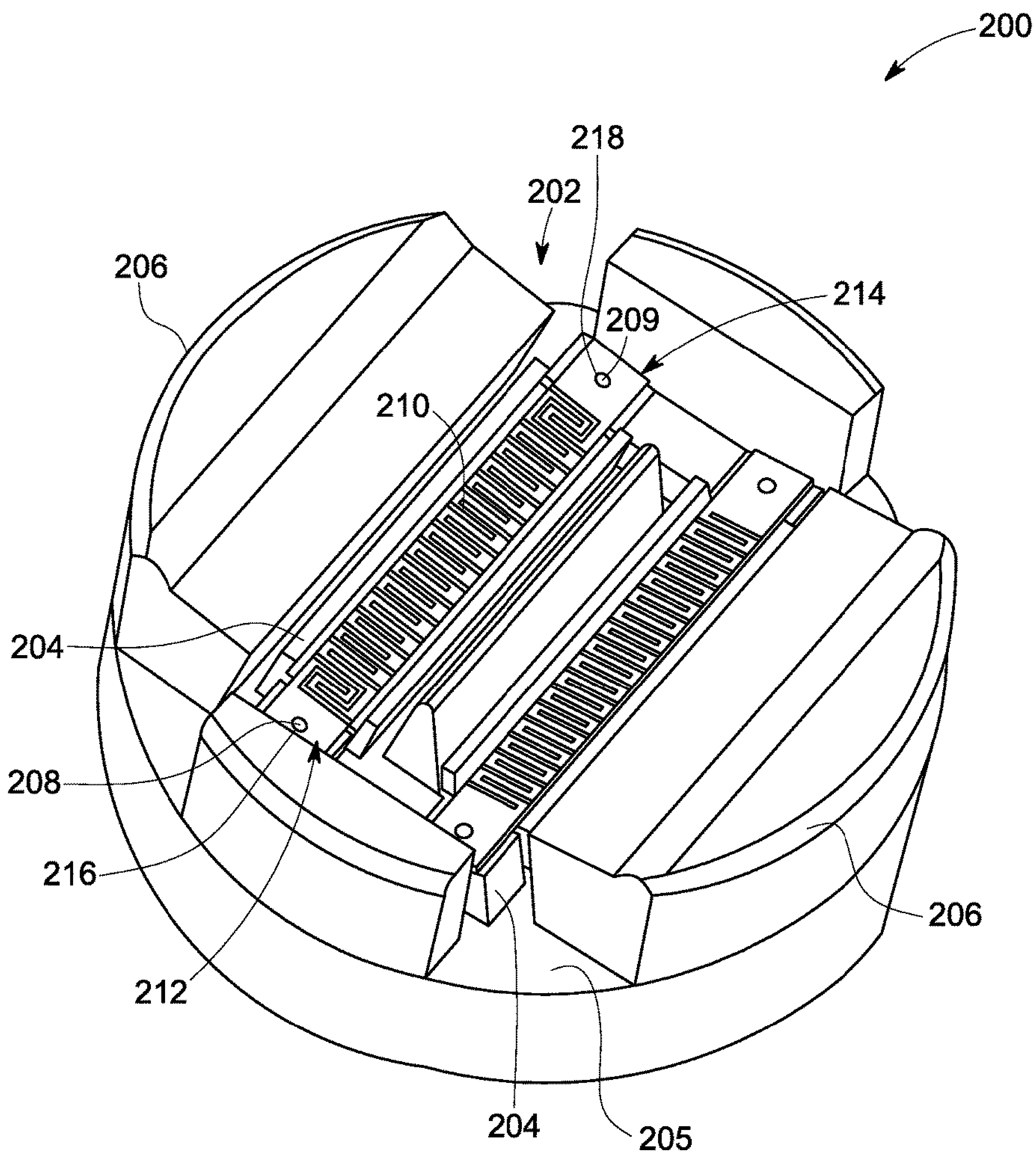

FIG. 2

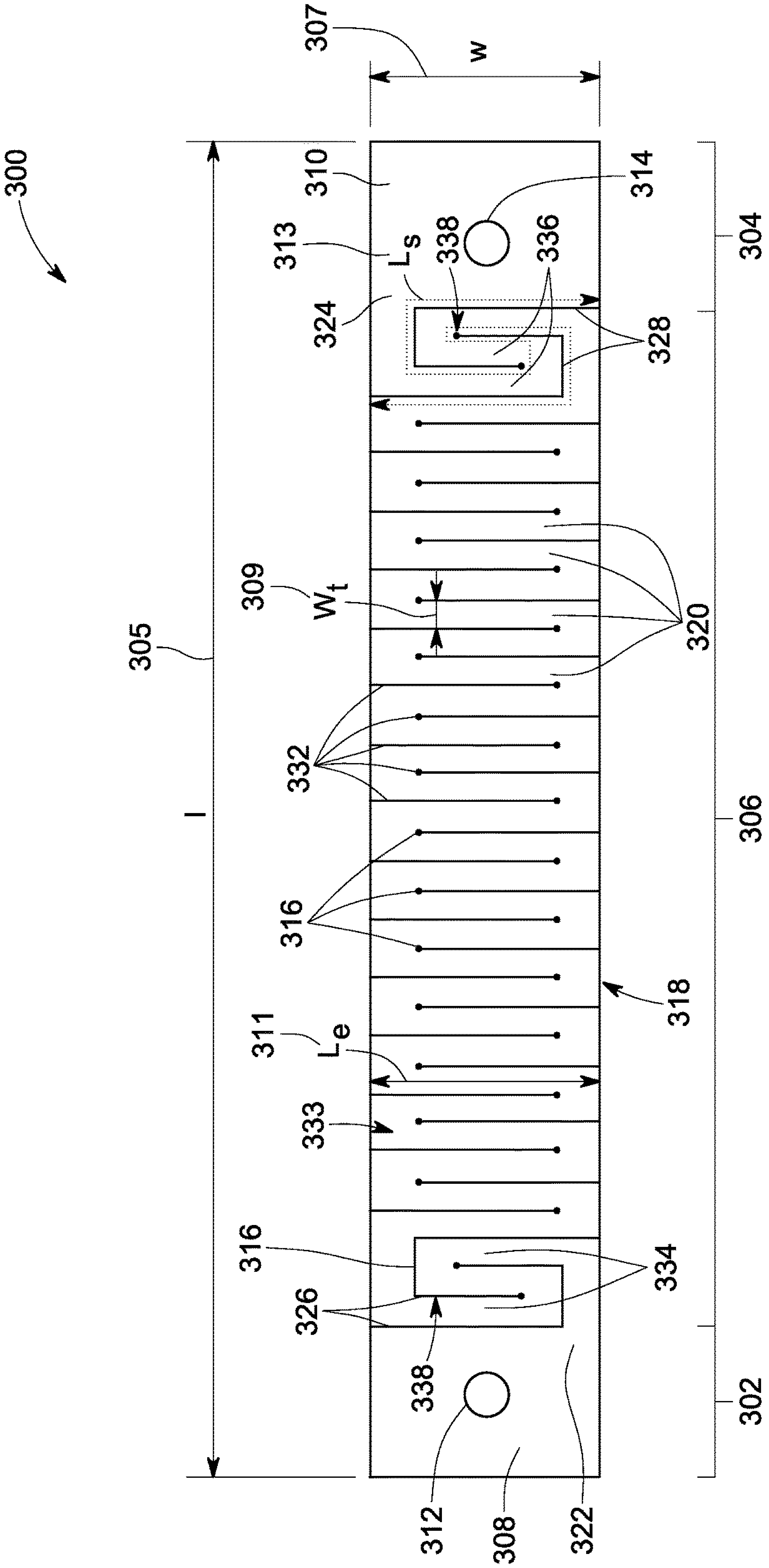
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FIG. 3

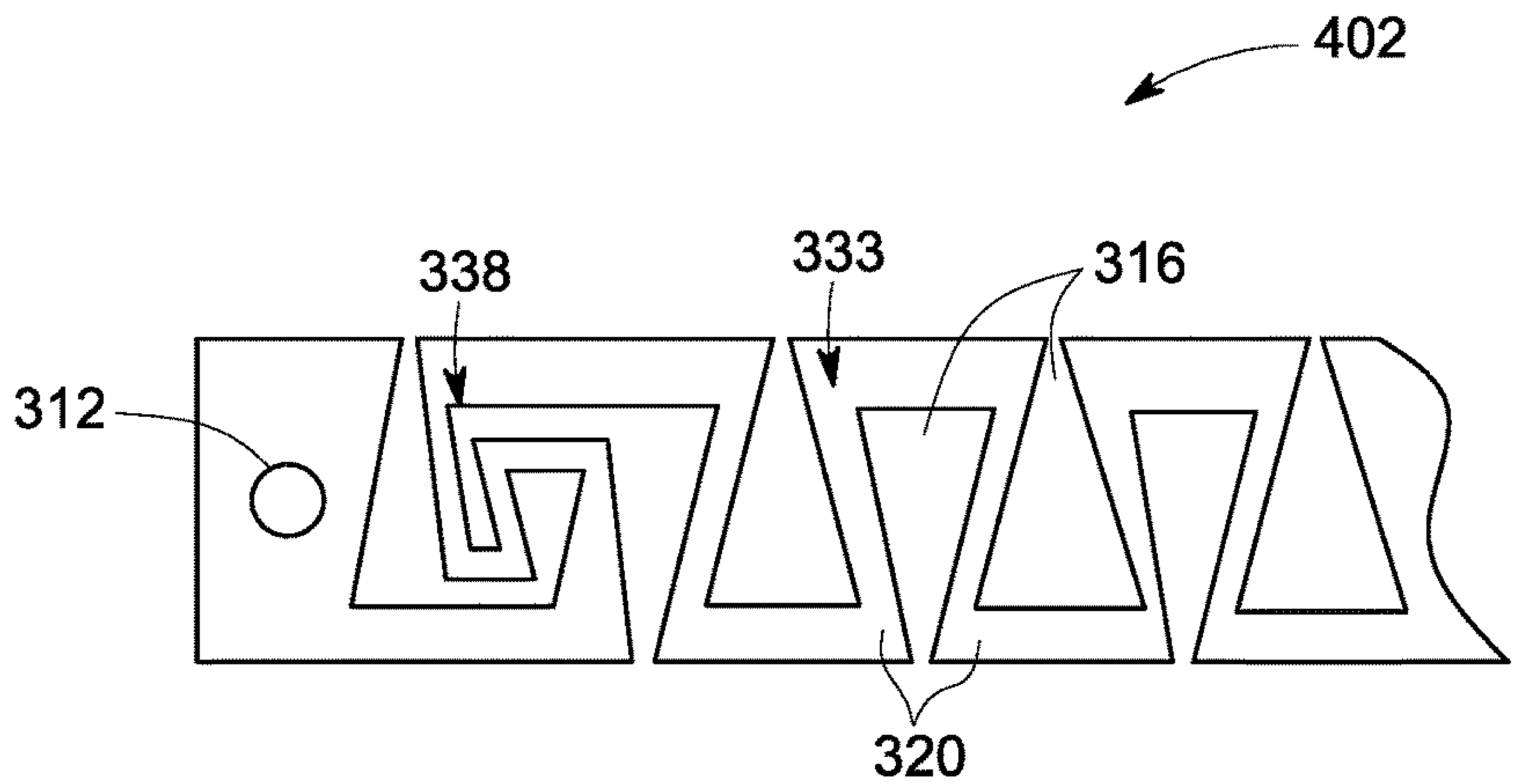

FIG. 4A

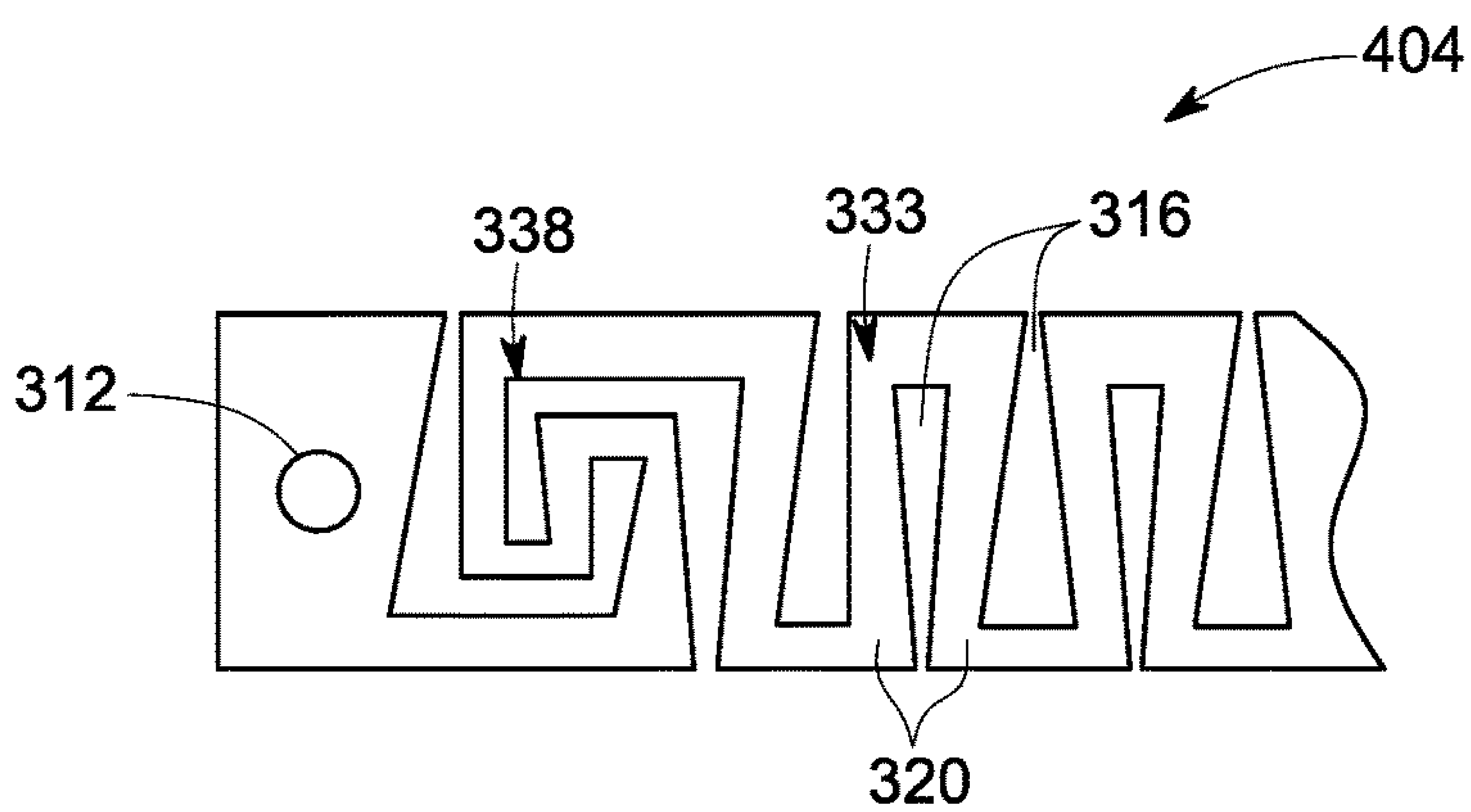

FIG. 4B

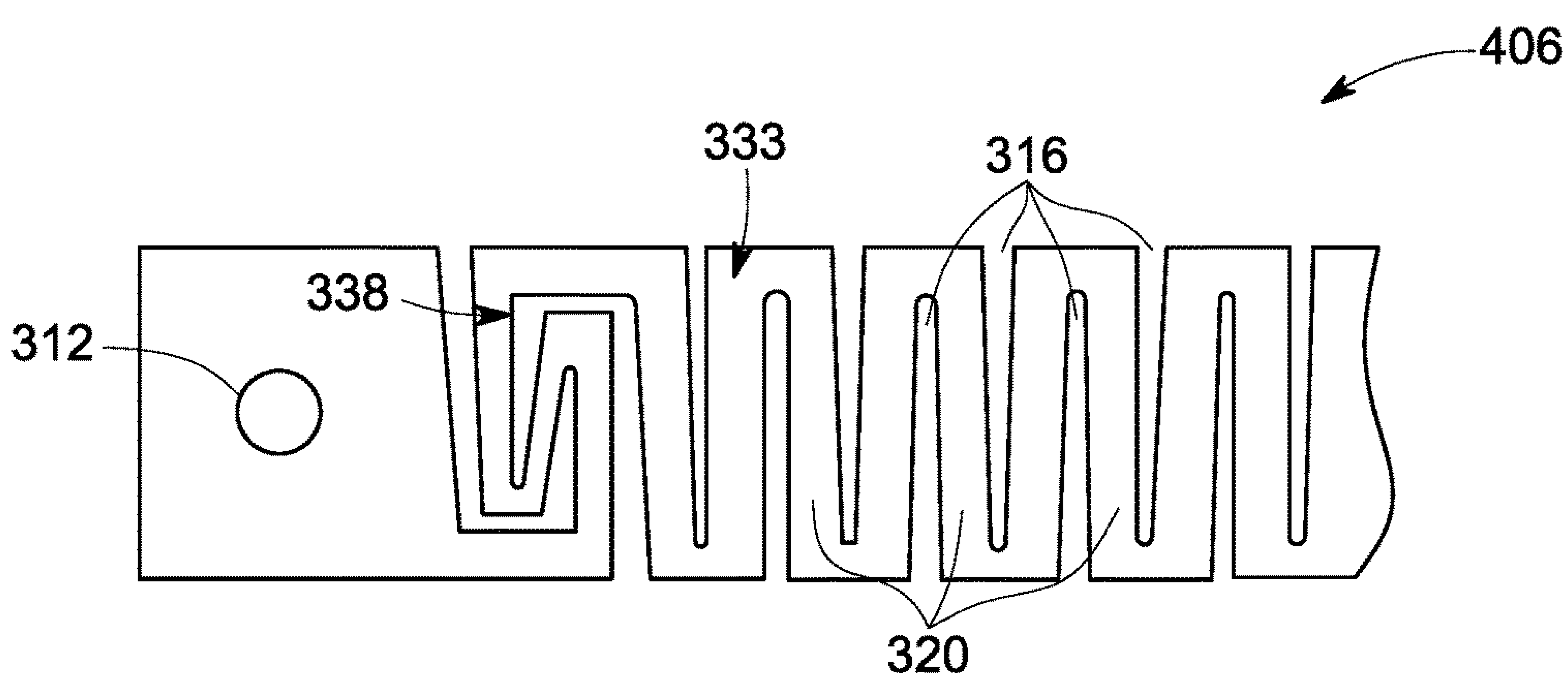

FIG. 4C

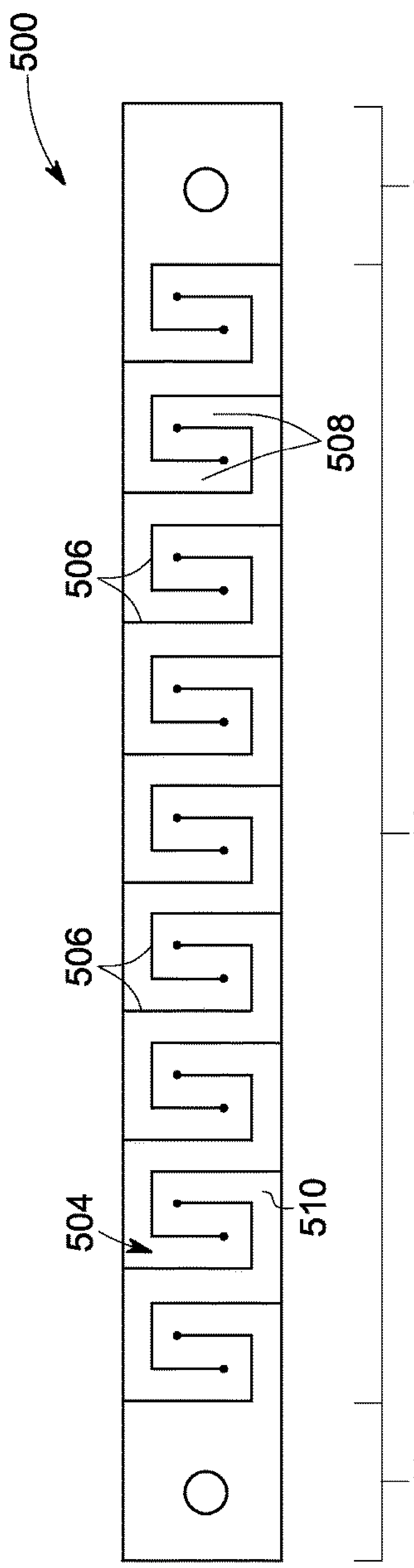
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FIG. 5

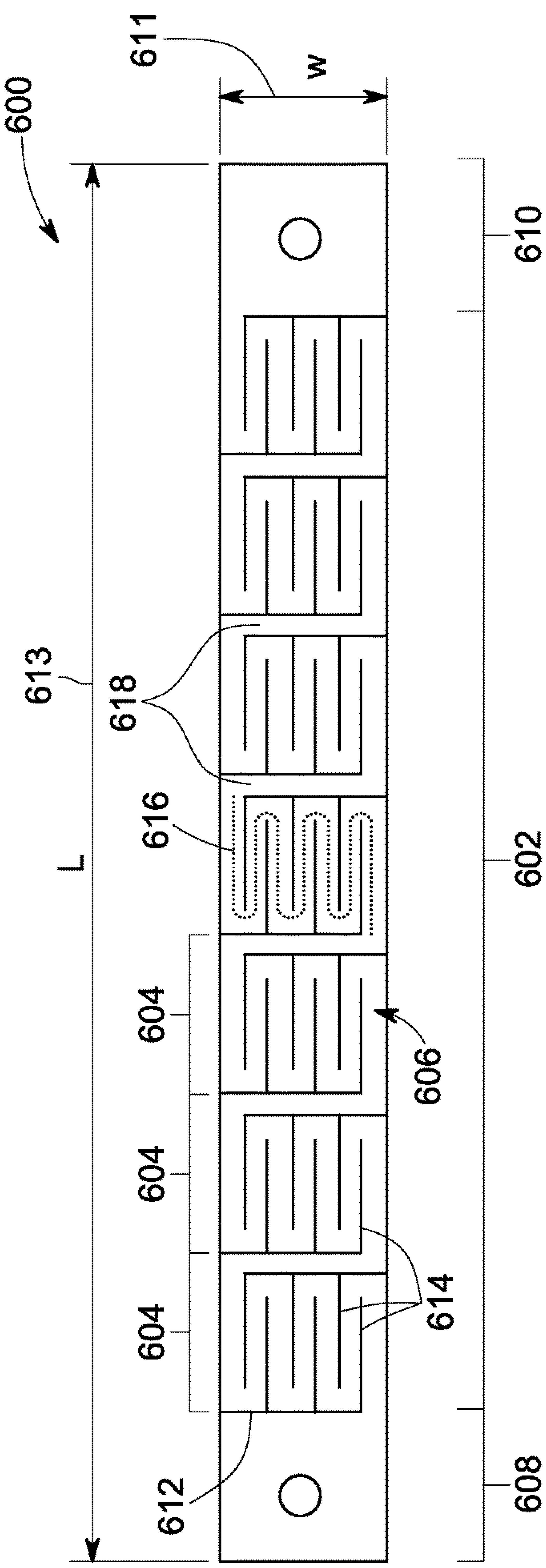
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FIG. 6

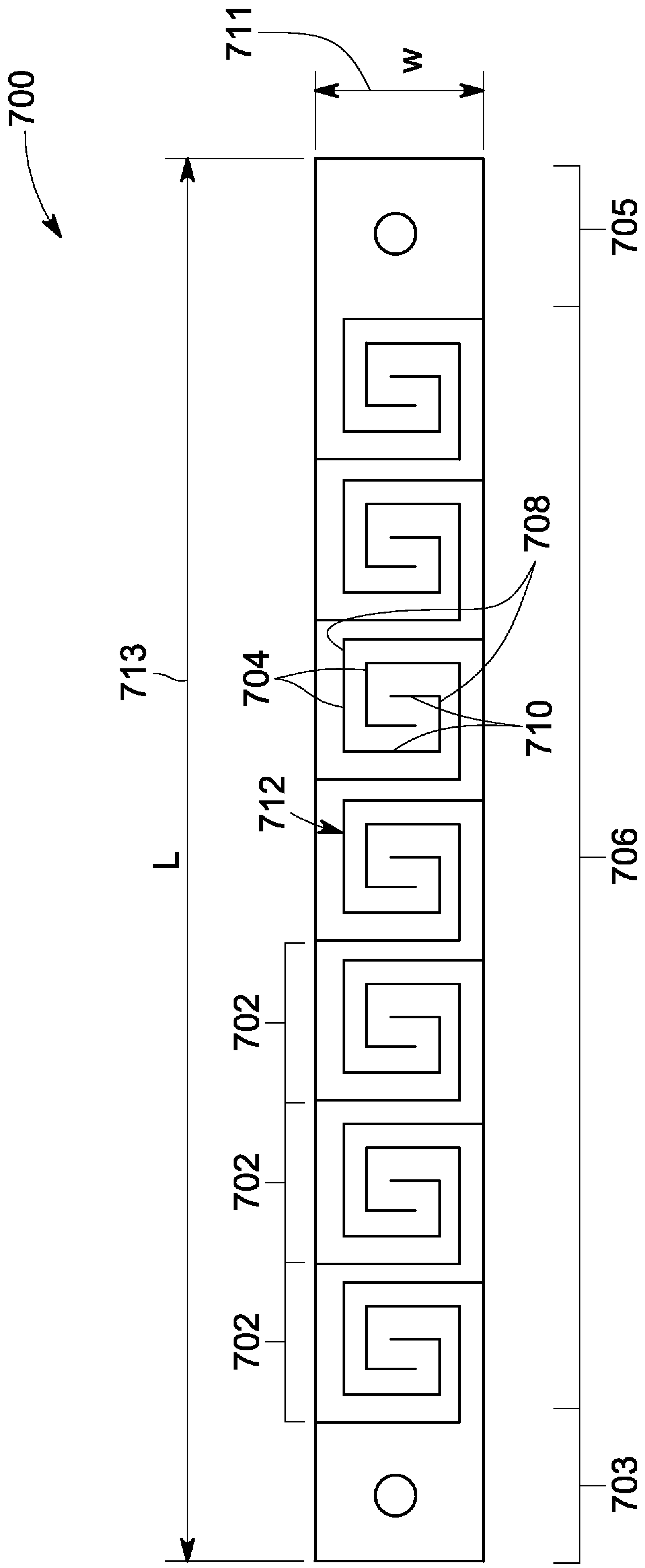

FIG. 7

FLEXIBLE FLAT EMITTER FOR X-RAY TUBES

BACKGROUND

Embodiments of the present specification relate generally to X-ray tubes, and more particularly to a flexible flat emitter in the X-ray tubes.

Typically, an X-ray tube is provided with tube current that heats an emitter in the X-ray tube to emit electrons towards a focal spot in the X-ray tube. In conventional systems, emitters are made of tungsten filament consisting of coiled wires. However, these filament emitters have very less emission area, which results in slow computed tomography (CT) scans or interventional scans. Also, as these emitters have small area, the emitters may heat up to a very high temperature during operation. As a consequence, the emitters may have very high evaporation rate that may physically damage the emitters and/or the X-ray tube.

In other conventional systems, thermionic flat emitters are employed in the X-ray tube for emitting the electrons. The thermionic flat emitters are more convenient to provide a larger emission area than traditional filament emitters. The thermionic flat emitters include emission segments that are separated by slots. Also, the area of flat emitters may be easily increased compared to the filament emitters. As a result, the temperature of the flat emitters is lower than the temperature of the filament emitters for similar amount of emission, and as a consequence the evaporation rate of the material of the flat emitters is less in comparison to that of the material of the filament emitters. Therefore, the flat emitters have an excellent life advantage. However, thermal cyclic deformation of the flat emitters is a challenge due to higher stiffness in the flat emitters. Particularly, when the emitters are subjected to cyclic thermal loading, it is often observed that the flat emitters exhibit lower flexibility as compared to the filament emitters. Due to lower flexibility, the flat emitters tend to distort/deform permanently over a period of time. Also, this deformation in the flat emitters may cause the flat emitters to lose their original shape and flatness. As a consequence, the focal spot quality of the flat emitters in the X-ray tube may degrade over a period of time.

BRIEF DESCRIPTION

In accordance with aspects of the present specification, a flat emitter configured for use in an X-ray tube is presented. The X-ray tube includes a first conductive section including a first terminal. Further, the X-ray tube includes a second conductive section including a second terminal. Also, the X-ray tube includes a third conductive section disposed between the first conductive section and the second conductive section, wherein the third conductive section is configured to emit electrons toward a determined focal spot, and wherein the third conductive section includes a plurality of slits subdividing the third conductive section into a winding track coupled to the first conductive section and the second conductive section, wherein at least two of the plurality of slits are interwound spirally to compose the winding track, and wherein the winding track is configured to expand and contract based on heat provided to the third conductive section.

In accordance with a further aspect of the present specification, an X-ray tube is presented. The X-ray tube includes a cathode unit configured to emit electrons toward an anode unit. Further, the cathode unit includes a cathode cup including a first voltage terminal and a second voltage terminal.

Also, the cathode unit includes a flat emitter coupled to the cathode cup. The flat emitter includes a first conductive section including a first terminal coupled to the first voltage terminal. Further, the flat emitter includes a second conductive section including a second terminal coupled to the second voltage terminal. Also, the flat emitter includes a third conductive section disposed between the first conductive section and the second conductive section, wherein the third conductive section is configured to emit the electrons toward a determined focal spot on the anode unit, and wherein the third conductive section includes a plurality of slits subdividing the third conductive section into a winding track coupled to the first conductive section and the second conductive section, wherein at least two of the plurality of slits are interwound spirally to compose the winding track and wherein the winding track is configured to expand and contract based on heat provided to the third conductive section.

In accordance with another aspect of the present specification, a method includes subdividing a conductive section in a flat emitter by a plurality of slits so as to compose a winding track between a first terminal and a second terminal of the flat emitter, wherein at least two of the plurality of slits are interwound spirally to compose the winding track, wherein the winding track is configured to provide one or more winding current paths in the conductive section, and wherein the winding track is configured to expand and contract based on heat provided to the conductive section.

DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. **1** is a cross sectional view of an X-ray tube, in accordance with aspects of the present specification;

FIG. **2** is a diagrammatical representation of a cathode cup having flat emitters, in accordance with aspects of the present specification;

FIG. **3** is a diagrammatical representation of a flat emitter having flexible emission segments, in accordance with aspects of the present specification;

FIGS. **4**A-**4**C are diagrammatical representation of stress experienced by the flat emitter of FIG. **3** subjected to different stages of cyclic thermal loading, in accordance with aspects of the present specification; and

FIGS. **5**-**7** are diagrammatical representations of flat emitters having different patterns of conductive tracks, in accordance with aspects of the present specification.

DETAILED DESCRIPTION

As will be described in detail hereinafter, various embodiments of exemplary systems and methods for controlling plastic deformation of a flat emitter are presented. In particular, the flat emitter presented herein at least partly controls mechanical stress imposed on the flat emitter during cyclic thermal loading, which, in turn, at least partly prevents the plastic deformation of the flat emitter. Also, by employing the exemplary flat emitter, evaporation rate of the flat emitter may be significantly reduced, thereby enhancing the life of the flat emitter.

Turning now to the drawings and referring to FIG. **1**, a cross sectional view of an X-ray tube **100**, in accordance with one embodiment of the present specification, is depicted. The X-ray tube **100** may be used for medical diagnostic examinations. In a presently contemplated configuration, the X-ray tube **100** includes a cathode assembly **102** and an anode assembly **104** that are disposed within an evacuated enclosure **106**. It may be noted that the X-ray tube **100** may include other components, and is not limited to the components shown in FIG. **1**. In general, the evacuated enclosure **106** may be a vacuum chamber that is positioned within a housing (not shown) of the X-ray tube **100**. Further, the cathode assembly **102** includes a cathode cup **108** that is configured to emit electrons towards the anode assembly **104**. Particularly, electric current is applied to an electron source, such as a flat emitter **110** in the cathode cup **108**, which causes electrons to be produced by thermionic emission. The electric current may be applied by a high voltage connector (not shown) that is electrically coupled between a voltage source (not shown) and the cathode assembly **102**.

Furthermore, the anode assembly **104** includes a rotary anode disc **112** and a stator (not shown). The stator is provided with necessary magnetic field to rotate the rotary anode disc **112**. Also, the rotary anode disc **112** is positioned in the direction of emitted electrons to receive the electrons from the cathode cup **108**. In one example, a copper base with a target surface having materials with high atomic numbers ("Z" numbers), such as rhodium, palladium, and/or tungsten, is employed in the rotary anode disc **112**. It may be noted that a stationary anode may also be used instead of the rotary anode disc **112** in the X-ray tube **100**.

During operation, the flat emitter **110** in the cathode cup **108** emits a beam of electrons that is accelerated towards the rotary anode disc **112** of the anode assembly **104** by applying a high voltage potential between the cathode assembly **102** and the anode assembly **104**. These electrons impinge upon the rotary anode disc **112** at a focal spot and release kinetic energy as electromagnetic radiation of very high frequency, i.e., X-rays. Particularly, the electrons are rapidly decelerated upon striking the rotary anode disc **112**, and in the process, the X-rays are generated therefrom. These X-rays emanate in all directions from the rotary anode disc **112**. A portion of these X-rays may pass through a window or X-ray port **114** of the evacuated enclosure **106** to exit the X-ray tube **100** and be utilized to interact in or on a material sample, patient, or other object (not shown).

Referring to FIG. **2**, a diagrammatical representation of a cathode cup **200** having flat emitters, in accordance with aspects of the present specification, is depicted. The cathode cup **200** may be similar to the cathode cup **108** of FIG. **1**. The cathode cup **200** includes a cavity structure **202** that is employed to focus electron beam towards a focal spot on an anode, such as a rotary anode disc **112** (see FIG. **1**) of the X-ray tube **100** (see FIG. **1**).

In a presently contemplated configuration, the cathode cup **200** includes one or more support tabs **204** on a bottom surface **205** of the cavity structure **202** and a focus tab **206** on sides of the cavity structure **202**. In the example of FIG. **2**, the cavity structure **202** includes two support tabs **204** that are separated from each other by a predetermined distance. It may be noted that the cavity structure **202** may include any number of support tabs, and is not limited to two support tabs. Also, for ease of understanding, only one support tab **204** is considered in the below description.

The support tab **204** is configured to hold a flat emitter **210** that is positioned upon the support tab **204**. Further, the support tab **204** includes conductive protrusions **208**, **209** at two ends of the support tab **204**. These conductive protrusions **208**, **209** are electrically conductive structures that are configured to act as voltage terminals, such as a first voltage terminal and a second voltage terminal for the flat emitter **210**. Consequently, the conductive protrusion **208** at one end may be referred to as a first voltage terminal, while the conductive protrusion **209** at the other end may be referred to as a second voltage terminal.

Further, the flat emitter **210** includes a first terminal **212** and a second terminal **214** at two opposite ends of the flat emitter **210**. Also, the first terminal **212** includes a first aperture or hole **216**, while the second terminal **214** includes a second aperture or hole **218**. Further, when the flat emitter **210** is mounted on the support tab **204**, the conductive protrusions **208**, **209** of the support tab **204** may overlap or extend out through the first aperture **216** and the second aperture **218** of the flat emitter **210**. Particularly, when the flat emitter **210** is mounted on the support tab **204**, the first voltage terminal of the support tab **204** may extend out through the first aperture **216** and may electrically couple with the first terminal **212** of the flat emitter **210**. In a similar manner, the second voltage terminal of the support tab **204** may extend out through the second aperture **218** and may electrically couple with the second terminal **214** of the flat emitter **210**.

Furthermore, the flat emitter **210** is provided with electric current by employing the first voltage terminal and the second voltage terminal of the support tab **204**. This electric current is used to heat the flat emitter **210** to a very high temperature, e.g., 2500° C., to provide or emit electrons from the flat emitter **210**. In one example, the electrons may be emitted from the flat emitter **210** by thermionic emission. Further, the focus tab **206** of the cathode cup **200** aids in focusing the emitted electrons towards the focal spot on the rotary anode disc **112**. Moreover, during operation, the flat emitter **210** may be subjected to a sequence of cooling and heating cycles to provide a desired beam of electrons towards the focal spot. These cooling and heating cycles may be referred to as cyclic thermal loading, which is explained in greater detail with reference to FIG. **4**.

Advantageously, the flat emitter **210** is configured to withstand cyclic thermal loading, while maintaining reasonable flexibility. Accordingly, the flat emitter **210** experiences lower mechanical stress and lower or negligible amounts of plastic deformation over a period of time. Consequently, the flat emitter **210** may be able to substantially retain its original shape as well as flatness. As a result, the focal spot quality of the X-ray tube may be retained.

In certain embodiments, the exemplary flat emitter **210** is employed in the cathode cup **200** to lower or substantially avoid plastic deformation and to improve the focal spot quality in the X-ray tube **100**. Particularly, the flat emitter **210** is provided with spring structure that is configured to expand and contract under cyclic thermal loading. Advantageously, this spring structure in the flat emitter **210** may aid in substantially reducing mechanical stress on the flat emitter **210**, which in turn reduces plastic deformation and improves the life of the flat emitter **210**. The aspect of reducing the plastic deformation in the flat emitter **210** is explained in greater detail with reference to FIG. **3**.

Referring to FIG. **3**, a diagrammatical representation of a flat emitter **300**, in accordance with aspects of the present specification, is depicted. It may be noted that the flat emitter **300** depicted in FIG. **3** is a pictorial representation, and is not drawn to a scale. The flat emitter **300** is a conductive strip that is divided into three conductive sections, such as a first conductive section **302**, a second conductive section **304**, and a third conductive section **306**. The first conductive section **302** and the second conductive section **304** are positioned at two ends of the flat emitter **300**, while the third conductive section **306** is positioned between the first conductive section **302** and the second conductive section **304**. Also, the third conductive section **306** is coupled to the first conductive section **302** and the second conductive section **304**, as depicted in FIG. **3**. Further, the length (1), represented by reference numeral **305**, of the flat emitter **300** is in a range from about 12 mm to about 20 mm. Also, the width (w), represented by reference numeral **307**, of the flat emitter **300** is in a range from about 1.5 mm to about 5 mm. Additionally, the thickness of the flat emitter **300** is in a range from about 50 μm to about 250 μm, wherein the thickness is represented by a dimension of the flat emitter **300** that is perpendicular to the plane of the paper. It may be noted that the illustrated designs/structures of the flat emitter should not be construed as restrictive, and that other such structures having spring like design are envisioned within the purview of the present application. Additionally, combinations of two or more designs illustrated in various FIGS. **5**-**7** in this application are also envisioned within the purview of the present application.

Further, the first conductive section **302** includes a first terminal **308**, while the second conductive section **304** includes a second terminal **310**. The first terminal **308** may include a first aperture **312** that is configured to electrically couple with a first voltage terminal **208** of the cathode cup **200** (see FIG. **2**). In a similar manner, the second terminal **310** may include a second aperture **314** that is configured to electrically couple with a second voltage terminal **209** of the cathode cup **200**. In one example, the diameter of the first aperture **312** and the second aperture **314** is in a range from 60 μm to 160 μm. In one embodiment, the terminals **308**, **310** of the flat emitter **300** may be coupled to the terminals **208**, **209** of the cathode cup **200** by welding, brazing, or other similar techniques.

In certain embodiments, the third conductive section **306** includes a plurality of slits or cuts **316** that define a winding track **318** in the third conductive section **306**. Particularly, the plurality of slits or cuts **316** are formed in a predefined pattern to obtain a plurality of emission segments **320** that are serially coupled/connected to each other. In one example, the width **307** of each of the plurality of slits **316** is in a range from about 20 μm to about 60 μm. Further, these individual connected emission segments **320** in the third conductive section **306** are collectively referred to as the winding track **318**. It may be noted that the winding track **318** is a physically continuous structure with no joints or cuts in between. However, in the present technique, the winding track **318** is shown as the segments serially connected to each other for understanding of the present technique. In one example, the plurality of slits or cuts **316** may be formed by using electrical discharge machining (EDM) or laser machining. Further, the winding track **318** includes a first end **322** coupled to the first conductive section **302** and a second end **324** coupled to the second conductive section **310**. Furthermore, the width (Wt), represented by reference numeral **309**, of the winding track **318** is in a range from about 0.2 mm to about 0.4 mm.

Moreover, in the exemplary embodiment of FIG. **3**, the plurality of slits **316** in the third conductive section **306** includes a first pair of bent slits **326**, a second pair of bent slits **328**, and a plurality of slits **332** between the first and second pairs of bent slits **326**, **328**. Further, the plurality of slits **332** may be positioned at one or more angles with respect to the length (1) **305** of the flat emitter **300** along the width (w) **307** of the flat emitter **300** to compose the connected emission segments **320** between the first pair of bent slits **326** and the second pair of bent slits **328** into a sinusoidal shape. Particularly, the slits **332** may aid in composing an up-down structure or serpentine structure of the connected emission segments **320** between the first pair of slits **326** and the second pair of slits **328**, as depicted in FIG. **3**. It may be noted that these emission segments **320** that are formed by the slits **332** are referred to as vertical emission segments **333**. Also, each of these vertical emission segments **333** may have a first determined length (Le) **311**. In one example, the first determined length (Le) **311** may be in a range from about 1.5 mm to 2.5 mm.

Further, the first pair of bent slits **326** is interwound spirally at the first end **322** of the third conductive section **306** to compose a pair of emission segments **334** into a spiral shape at the first end **322**, as depicted in FIG. **3**. Similarly, the second pair of bent slits **328** is interwound spirally at the second end **324** of the third conductive section **306** to compose a pair of emission segments **336** into a spiral shape at the second end **324**. In one embodiment, each bent slit of the first pair and the second pair of bent slits **326**, **328** includes three arms, such that two arms are parallel to one another and at 90 degrees angle to another arm that is coupled to the two arms. However, it may be noted that the arms may or may not be parallel to one another. Non-limiting examples of the bent slits **326**, **328** may include V-shaped slits, U-shaped, trapezoidal slits. It may be noted that length of the arms of the bent slits **326**, **328** may or may not be same. Also, where one arm of the bent slits **326**, **328** may be perpendicular to at least one other arm. It may be noted that the emission segments **334**, **336** in a spiral shape are referred to as spiral emission segments **338**. In one example, these spiral emission segments **338** may have a second determined length (Ls) **313** that is about twice the first determined length (Le) **311**. Particularly, the spiral emission segments **338** are longer in length compared to the vertical emission segments **333**. In one example, the second determined length (Ls) **313** may be in a range from about 2 mm to 5 mm. It may be noted that each of the spiral emission segments **338** may also be referred as a folded ribbon structure.

During operation, these spiral emission segments **338** may act like spring structure and may substantially reduce stiffness at the ends **322**, **324** of the third conductive section **306**. Also, as these spiral emission segments **338** are longer in length compared to the length of the vertical emission segments **333**, the spiral emission segments **338** may provide larger deflection compared to the vertical emission segments **333**. Particularly, as depicted in FIGS. **4A**-**4C**, the flat emitter **300** along with the cathode cup **200** may be subjected to different cycles or stages of cyclic thermal loading while emitting the electrons. The flat emitter **300** depicted in FIGS. **4A**-**4C** is a pictorial representation, and is not drawn to a scale. For example, as depicted in FIG. **4A**, in a first cycle or stage **402**, electric current is supplied to the flat emitter **300** to heat the flat emitter **300** to a determined temperature. In this stage **402**, the flat emitter **300** is hot, while the cathode cup **200** is cold. Hence, the emission segments **333** in the third conductive section **306** may expand and create compressive stress at the hole or aperture **312**, **314** of the flat emitter **300**. In one example, the compressive stress may be around 500 MPa. However, the spiral emission segments **338** in the flat emitter **300** may provide more elasticity at the ends of the third conductive section **306**, which in turn reduces the compressive stress on the flat emitter **300**. As a consequence, deformation of the flat emitter **300** may be substantially reduced.

Further, as depicted in FIG. **4B**, in a second cycle or stage **404**, the flat emitter **300** is maintained hot and the cathode cup **200** is also heated. As the cathode cup **200** is heated, the compressive stress is released in the flat emitter **300**. Particularly, the heat is distributed across the flat emitter **300** and the cathode cup **200**, which in turn reduces the stress in the flat emitter **300**. In one embodiment, the stress may be reduced by 30% of the compressive stress in the first cycle or stage **402**. In one example, the stress in this stage **404** is around 380 MPa. However, the spiral emission segments **338** in the flat emitter **300** may provide more elasticity at the ends of the third conductive section **306**, which in turn reduces the compressive stress on the flat emitter **300**. As a consequence, deformation of the flat emitter **300** may be substantially reduced. Moreover, in this stage **404**, the temperature difference between the flat emitter **300** and the cathode cup **200** is low. Hence, the stress in this stage **404** is less than the stress in the stage **402**.

Furthermore, as depicted in FIG. **4**C, in a third cycle or stage **406**, supply of electric current to the flat emitter **300** is seized. This, in turn cools the flat emitter **300**. However, the heat present in the cathode cup **200** may not be reduced instantly. In one example, the heat in the cathode cup **200** may gradually reduce over a relatively longer time than the flat emitter **300**. Thus, in the third stage **406**, the flat emitter **300** may be colder than the cathode cup **200**. Hence, the emission segments **333** in the third conductive section **306** may relax and create tensile stress at the holes or apertures **312**, **314** of the flat emitter **300**. In one example, the tensile stress on the flat emitter **300** may be around 228 MPa. Here again, the spiral emission segments **338** in the flat emitter **300** may provide more elasticity at the ends of the third conductive section **306**, which in turn reduces the tensile stress on the flat emitter **300**. As a consequence, undesirable deformation of the flat emitter **300** may be substantially reduced.

Advantageously, the spiral emission elements **338** of the exemplary flat emitter **300** are configured to substantially reduce the mechanical stress otherwise imposed by cyclic thermal loading on the flat emitter **300**. Also, the spiral elements **338** of the exemplary flat emitter **300** are configured to prevent or substantially reduce plastic deformation of the flat emitter **300**, which in turn facilitates in maintaining the focal spot quality in the X-ray tube. It may be noted that the illustrated designs/structures of the flat emitter should not be construed as restrictive, and that other such structures having spring like design are envisioned within the purview of the present application.

Referring to FIG. **5**, a diagrammatical representation of a flat emitter **500**, in accordance with another embodiment of the present specification, is depicted. The flat emitter **500** is similar to the flat emitter **300** of FIG. **3**. In the illustrated embodiment, the flat emitter **500** has a third conductive section **502** that includes only spiral emission segments **504**. Particularly, the third conductive section **502** includes a plurality of pairs of slits **506** that are interwound spirally to compose pairs of emission segments **508** into a spiral shape. Also, these pairs of emission segments **508** are serially connected to each other to form a winding track **510** between a first conductive section **512** and a second conductive section **514** of the flat emitter **500**.

During operation, the spiral emission segments **504** in the flat emitter **500** may provide winding current paths along the third conductive section **502** of the flat emitter **500**. Further, when electric current flows through these meandering current paths, the flat emitter **500** is heated to a very high temperature, e.g., 2500° C. At this high temperature, the flat emitter **500** may expand and may induce mechanical stress, particularly at the ends of the flat emitter **500**. However, the exemplary flat emitter **500** includes spiral emission segments **504** that are longer in length and may act like spring structure when the flat emitter **500** is heated to this high temperature. This in turn, reduces mechanical stress on the flat emitter **500** and may prevent plastic deformation of the flat emitter **500**.

Turning to FIG. **6**, a diagrammatical representation of a flat emitter **600**, in accordance with yet another embodiment of the present specification, is depicted. The flat emitter **600** is similar to the flat emitter **300** of FIG. **3**. In the illustrated embodiment, a third conductive section **602** of the flat emitter **600** includes a plurality of sub-tracks **604** that are serially coupled to each other to compose a winding track **606** between a first conductive section **608** and a second conductive section **610**. In one example, each of the sub-tracks **604** may be referred to as a current conducting path that is between two adjacent vertical emission segments **618**. Further, each of these sub-tracks **604** has a sinusoidal shape along the width (W) **611** of the flat emitter **600**. Particularly, the third conductive section **602** is subdivided by a plurality of vertical slits **612** and horizontal slits **614** in a predefined pattern to compose the third conductive section **602** in a sequence of sub-tracks **602** that are serially connected to each other, as depicted in FIG. **6**. The vertical slits **612** and horizontal slits **614** are referred to with reference to the length (L) **613** of the flat emitter **600**. By way of example, the vertical slits **612** are positioned perpendicular to the length (L) **613** of the flat emitter **600**. Similarly, the horizontal slits **614** are positioned parallel to the length (L) **613** of the flat emitter **600**. Also, each of these sub-tracks **604** includes an up-down structure of emission segment **616** arranged in a sinusoidal shape. It may be noted that an emission segment **616** in each sub-track may be referred to as sinusoidal emission segment. The sinusoidal emission segment **616** in each sub-track **604** is positioned in a longitudinal direction that is, along the length (L) **613** of the flat emitter. Also, this sinusoidal emission segment **616** in each sub-track **604** may provide winding current paths in the third conductive section **602**.

Further, the sinusoidal emission segment **616** has longer length compared to the spiral emission segment **338** in FIG. **3**. Additionally, a S-shaped link between the sinusoidal emission segments **616** has longer length. This in turn helps in providing larger deflection when the flat emitter **600** is subjected to heating and cooling cycles. As a consequence, the flat emitter **600** may have less mechanical stress and minimal or no plastic deformation in the flat emitter **600**.

Referring to FIG. **7**, a diagrammatical representation of a flat emitter **700**, in accordance with yet another embodiment of the present specification, is depicted. The flat emitter **700** is similar to the flat emitter **600** of FIG. **3**. In particular, the flat emitter **700** includes a first conductive section **703**, a second conductive section **705**, and a third conductive section **706**. Further, the third conductive section **706** includes one or more sub-tracks **702** that are composed into a spiral shape. Particularly, each of the sub-tracks **702** is composed by a pair of slits **702** that are interwound spirally in the third conductive section **706**. Also, each of the pair of slits **704** includes at least two horizontal slits **708** and two vertical slits **710** that are alternately connected to each other to form a single spiral slit, as depicted in FIG. **7**. The horizontal slits **708** and vertical slits **710** are referred to with reference to the length (L) **713** of the flat emitter **700**. By way of example, the vertical slits **710** are positioned perpendicular to the length (L) **713** of the flat emitter **700**. Similarly, the horizontal slits **708** are positioned parallel to the length (L) **713** of the flat emitter **700**. It may be noted that an emission segment **712** in each sub-track **702** may be referred to as double spiral emission segment. Moreover, the double spiral emission segment **712** in each sub-track **704** is positioned along the width (W) **711** of the flat emitter **700**. Also, this spiral emission segment **712** in each sub-track **702** may provide winding current paths in the third conductive section **706**.

Further, the double spiral emission segment **712** may have longer length compared to the spiral emission segments **338** of FIG. **3**. This in turn helps in providing larger deflection when the flat emitter **700** is subjected to heating and cooling cycles. As a consequence, the flat emitter **700** may have less mechanical stress and minimal or no plastic deformation.

In one another embodiment, the plurality of slits may include a first number of slits that are arranged vertically and/or horizontally to compose at least a portion of the winding track into a sinusoidal shape. In yet another embodiment, the plurality of slits may include a second number of slits that are arranged spirally to compose at least a portion of the winding track into a spiral shape.

During operation, these emission segments in the winding track may provide elasticity to the flat emitter. Particularly, when the flat emitter is subjected to cyclic thermal loading, the emission segments in the flat emitter may provide larger deflection compared to the conventional flat emitter. As a result of this larger deflection in the flat emitter, mechanical stress on the flat emitter may be substantially reduced. This in turn prevents plastic deformation of the flat emitter. Also, by employing the exemplary flat emitter, evaporation rate of the flat emitter may be significantly reduced. This in turn improves the life of the emitter and reduces maintenance cost of the X-ray cathode and the X-ray tube.

While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

The invention claimed is:

1. A flat emitter configured for use in an X-ray tube, comprising:

a first conductive section comprising a first terminal;

a second conductive section comprising a second terminal; and

a third conductive section disposed between the first conductive section and the second conductive section, wherein the third conductive section is configured to emit electrons toward a determined focal spot,

wherein the third conductive section comprises a plurality of slits subdividing the third conductive section into a winding track coupled to the first conductive section and the second conductive section, wherein at least two of the plurality of slits are interwound spirally to compose the winding track, wherein the winding track is configured to expand and contract based on heat provided to the third conductive section, and

wherein a determined number of the plurality of slits are arranged vertically in the third conductive section to compose the winding track into a sinusoidal shape.

2. The flat emitter of claim **1**, wherein the winding track is configured to provide one or more winding current paths along the third conductive section.

3. The flat emitter of claim **1**, wherein a second number of the plurality of slits are arranged spirally in the third conductive section to compose the winding track into a spiral shape.

4. The flat emitter of claim **1**, wherein the winding track comprises a plurality of sub-tracks serially coupled to each other.

5. The flat emitter of claim **4**, wherein each of the plurality of sub-tracks is composed into at least one of a sinusoidal shape and a spiral shape.

6. The flat emitter of claim **5**, wherein each of the plurality of sub-tracks is composed into the spiral shape by spirally interwinding at least two of the plurality of slits.

7. The flat emitter of claim **1**, wherein a combined length of the first conductive section, the second conductive section, and the third conductive section is in a range from 12 mm to 20 mm.

8. The flat emitter of claim **1**, wherein a width of each of the first conductive section, the second conductive section, and the third conductive section is in a range from 1.5 mm to 5 mm.

9. The flat emitter of claim **1**, wherein a thickness of each of the first conductive section, the second conductive section, and the third conductive section is in a range from 50 microns to 250 microns.

10. The flat emitter of claim **1**, wherein a width of the winding track is in a range from 0.2 mm to 0.4 mm.

11. The flat emitter of claim **1**, wherein a width of each of the plurality of slits is in a range from 40 μm to 60 μm.

12. The flat emitter of claim **1**, wherein the first terminal comprises a first aperture configured to be electrically coupled to a first voltage terminal of a cathode cup in the X-ray tube.

13. The flat emitter of claim **12**, wherein a diameter of the first aperture is in a range from 60 μm to 160 μm.

14. The flat emitter of claim **12**, wherein the second terminal comprises a second aperture configured to be electrically coupled to a second voltage terminal of the cathode cup in the X-ray tube.

15. The flat emitter of claim **14**, wherein a diameter of the second aperture is in a range from 60 μm to 160 μm.

16. A flat emitter configured for use in an X-ray tube, comprising:

a first conductive section comprising a first terminal;

a second conductive section comprising a second terminal; and

a third conductive section disposed between the first conductive section and the second conductive section, wherein the third conductive section is configured to emit electrons toward a determined focal spot,

wherein the third conductive section comprises a plurality of slits subdividing the third conductive section into a winding track coupled to the first conductive section and the second conductive section, wherein at least two of the plurality of slits are interwound spirally to compose the winding track, wherein the winding track is configured to expand and contract based on heat provided to the third conductive section,

wherein the winding track comprises a plurality of sub-tracks serially coupled to each other, and wherein each of the plurality of sub-tracks is composed into at least one of a sinusoidal shape and a spiral shape.

17. The flat emitter of claim **16**, wherein each of the plurality of sub-tracks is composed into the spiral shape by spirally interwinding at least two of the plurality of slits.

18. An X-ray tube comprising:

an anode unit;

a cathode unit configured to emit electrons toward the anode unit, wherein the cathode unit comprises:

a cathode cup comprising a first voltage terminal and a second voltage terminal;

a flat emitter coupled to the cathode cup and comprising:

a first conductive section comprising a first terminal coupled to the first voltage terminal;

a second conductive section comprising a second terminal coupled to the second voltage terminal; and

a third conductive section disposed between the first conductive section and the second conductive section, wherein the third conductive section is configured to emit the electrons toward a determined focal spot on the anode unit,

wherein the third conductive section comprises a plurality of slits subdividing the third conductive section into a winding track coupled to the first conductive section and the second conductive section, wherein at least two of the plurality of slits are interwound spirally to compose the winding track, wherein the winding track is configured to expand and contract based on heat provided to the third conductive section, and

wherein a determined number of the plurality of slits are arranged vertically in the third conductive section to compose the winding track into a sinusoidal shape.

19. The X-ray tube of claim **18**, wherein the winding track is configured to provide one or more winding current paths in the third conductive section.

20. A method comprising:

subdividing a conductive section in a flat emitter by a plurality of slits so as to compose a winding track between a first terminal and a second terminal of the flat emitter, wherein at least two of the plurality of slits are interwound spirally to compose the winding track,

wherein the winding track is configured to provide one or more winding current paths in the conductive section, wherein the winding track is configured to expand and contract based on heat provided to the conductive section, and

wherein subdividing the conductive section comprises arranging a first number of the plurality of slits vertically to compose at least a portion of the winding track into a sinusoidal shape.

21. The method of claim **20**, wherein subdividing the conductive section comprises arranging a second number of the plurality of slits spirally to compose the winding track into a spiral shape.

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